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# *Supernovae Simulations and Strategies: Application to the Dark Energy Survey*


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# Outline

- DES-Supernovae (DES-SN) Overview
- SNANA: SN light curve simulation & fitter
- DES-SN Selection Bias
- DES-SN Non-Ia Contamination
- SNANA in the Infrared
- Summary & Conclusions

DARK ENERGY SURVEY

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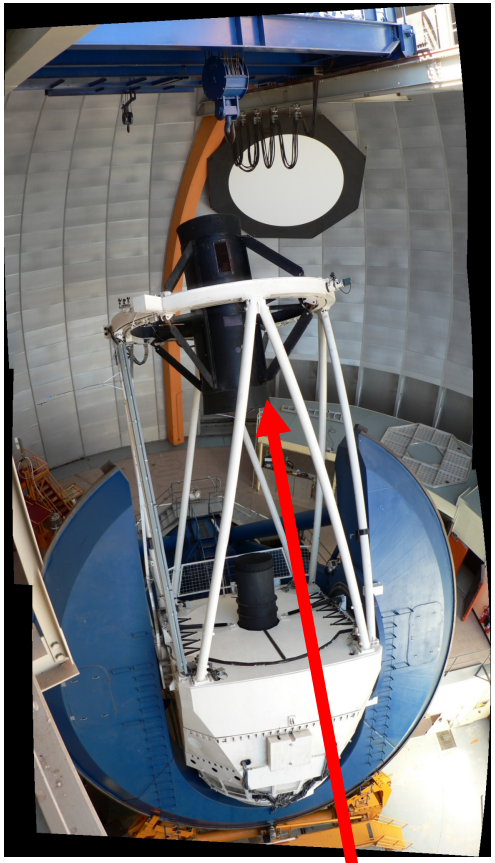
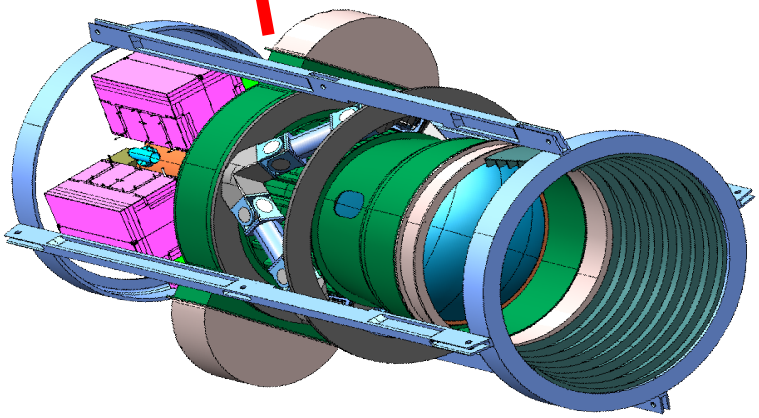


# Dark Energy Survey (DES)

DES is providing a new 520Mpixel CCD camera (DECAM) for the Blanco 4m telescope in Chile in exchange for 525 survey nights over 5 year period for a 5000 square degree survey starting in 2011

DES uses thicker CCDs from Lawrence Berkeley National Laboratory with increased red sensitivity



# DES Supernovae

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- DES time allocation fixes total supernovae (SNe) exposure time
  - 1260 hr planned over 5-year survey
  - maximal use of non-photometric time (~920 hr or 73%) planned
- Time per field & number of fields can be simulation optimized
  - ultra-deep strategy (3 square degrees = 1 DES field)
  - deep strategy (9 square deg.)*
  - shallow but wide strategy (27 square deg.)
  - hybrid strategy, e.g., 2 deep + 3 wide (15 square deg.)
- Results show hybrid strategy is best (more later)

* Highlighted in DES DOE proposal

# *Currently Favored DES-SN Fields*

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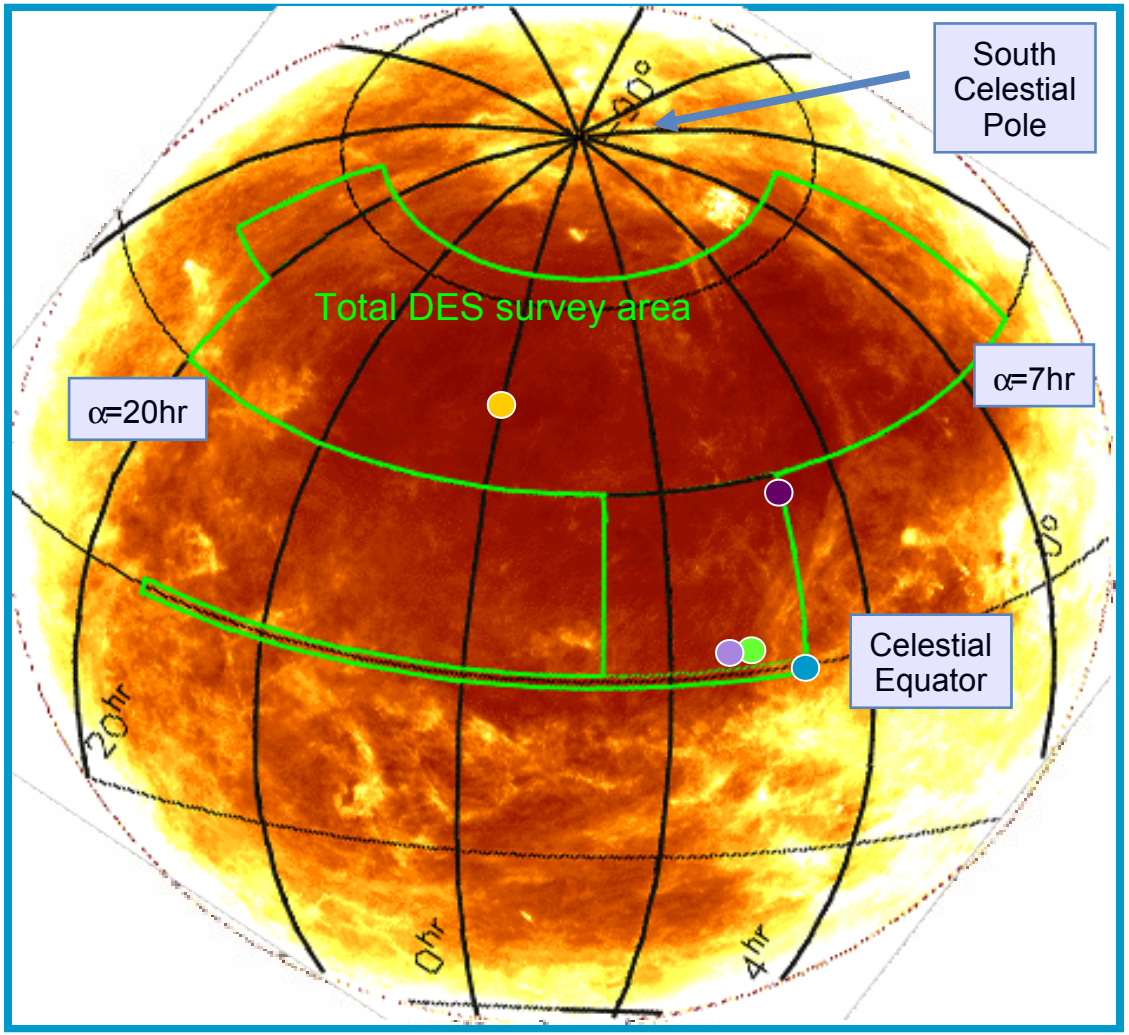
- Chosen to maximize:
  - visibility from DES site
  - past observation history
  - visibility from, e.g., Hawaii

Chandra Deep Field – South
Sloan Stripe 82
SN Legacy Survey (SNLS) D1
XMM-Newton LSS
ELAIS S1

From a study by Peter Nugent



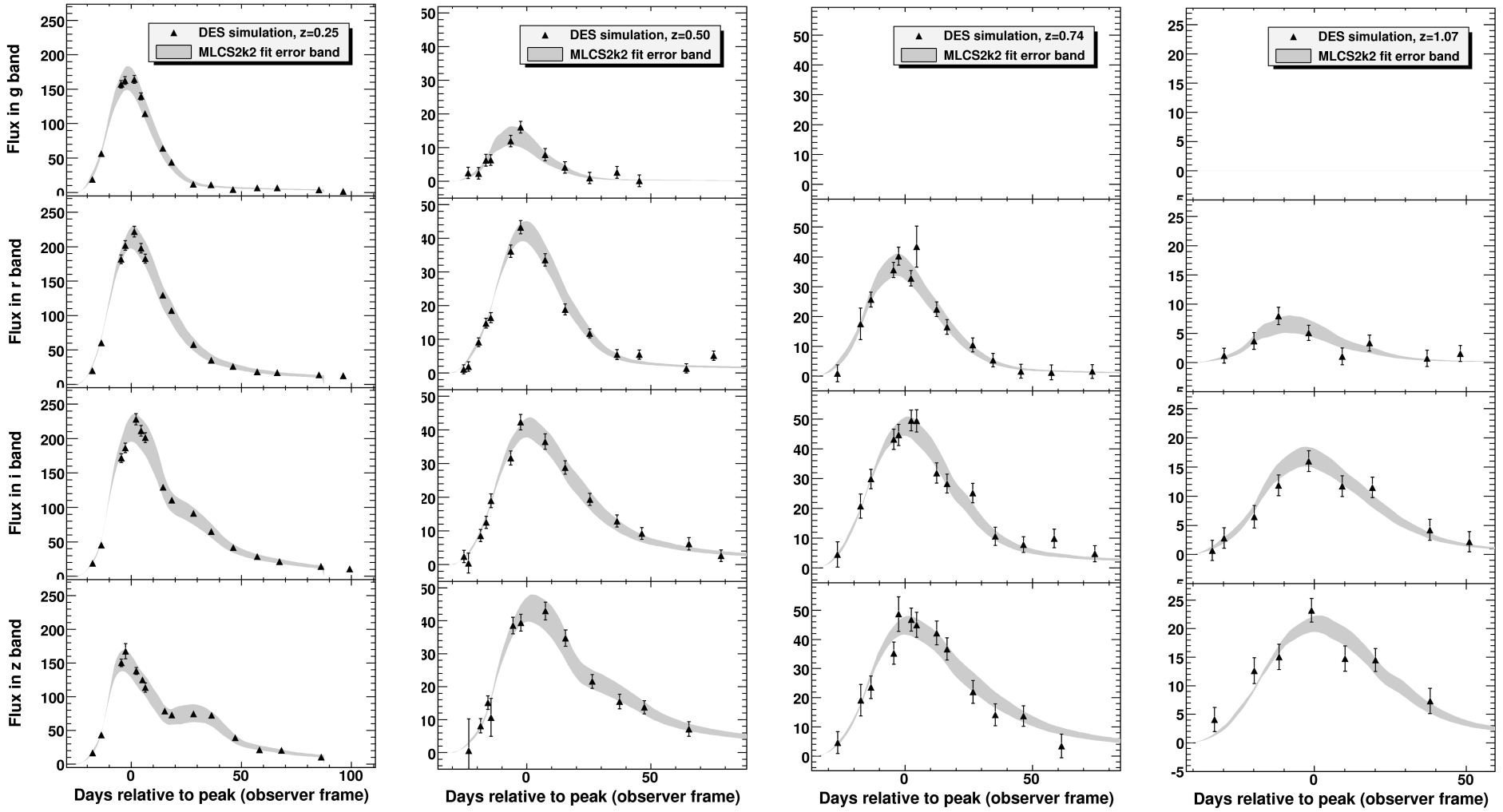
# *SNANA: SuperNova ANAlysis package for DES*

DARK ENERGY SURVEY

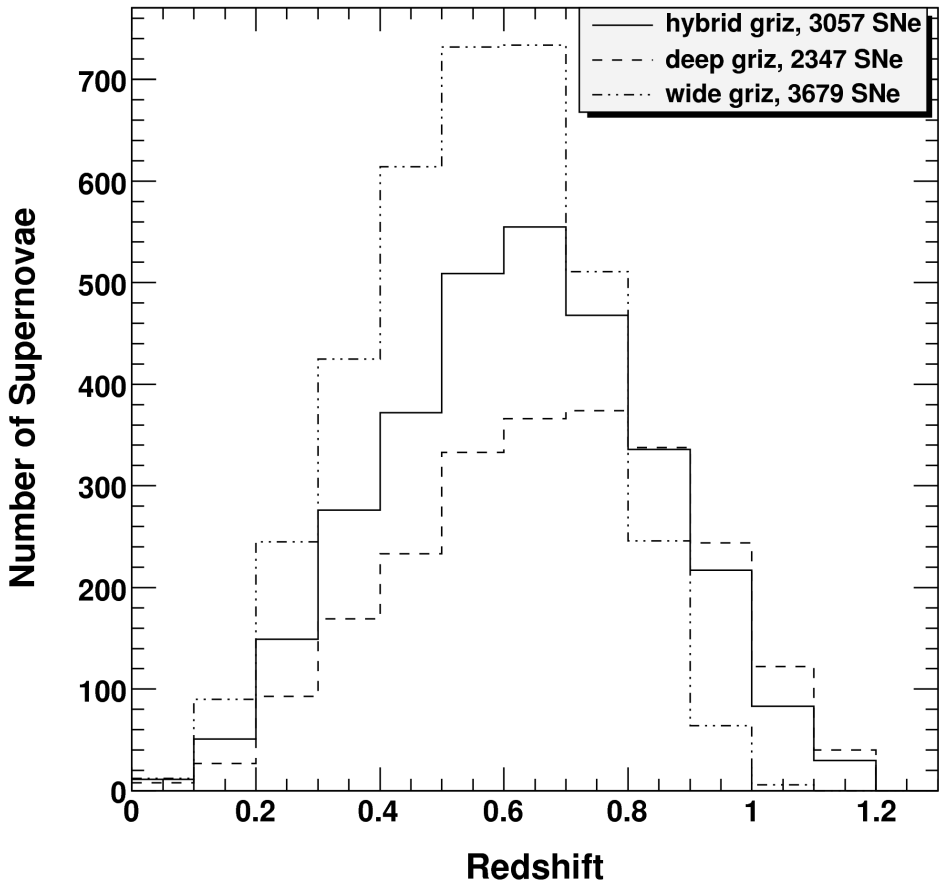
R. Kessler (U. Chicago), J. P. Bernstein, S. Kuhlmann, & H. Spinka (ANL)

- Public URL: http://www.sdss.org/supernova/SNANA.html
- Also used by SDSS & LSST
- Software suite for simulating and fitting SN light curves
- Motivation was a more accurate and complete study of DES-SN capabilities including DES CCD and filter characteristics, CTIO sky fluctuations using Essence data inputs, dust extinction effects, etc.
- Uses various models (e.g., MLCS2k2, SALT-II, stretch, etc.)
- Models and fits both Ia and non-Ia SNe

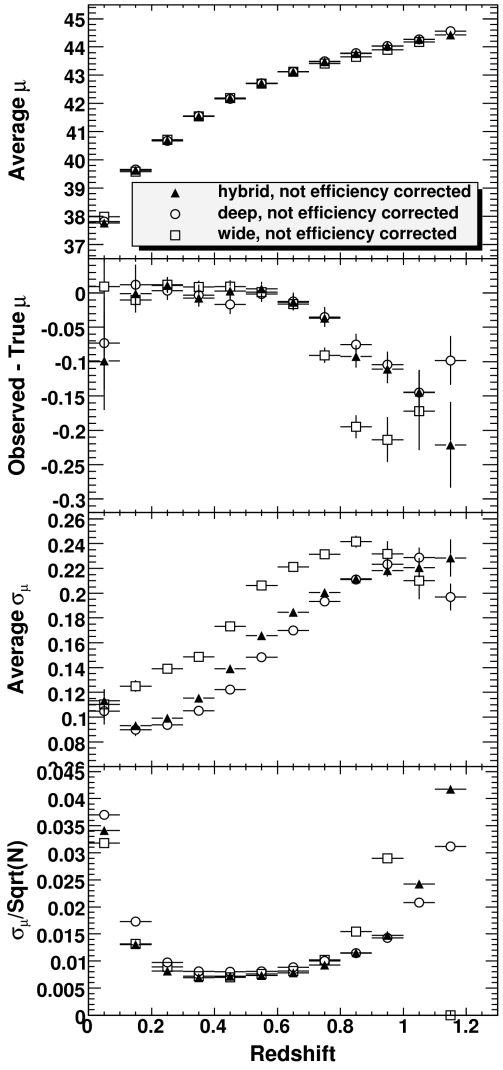
# Example Simulated MLCS2k2 DES SN Ia Light Curves

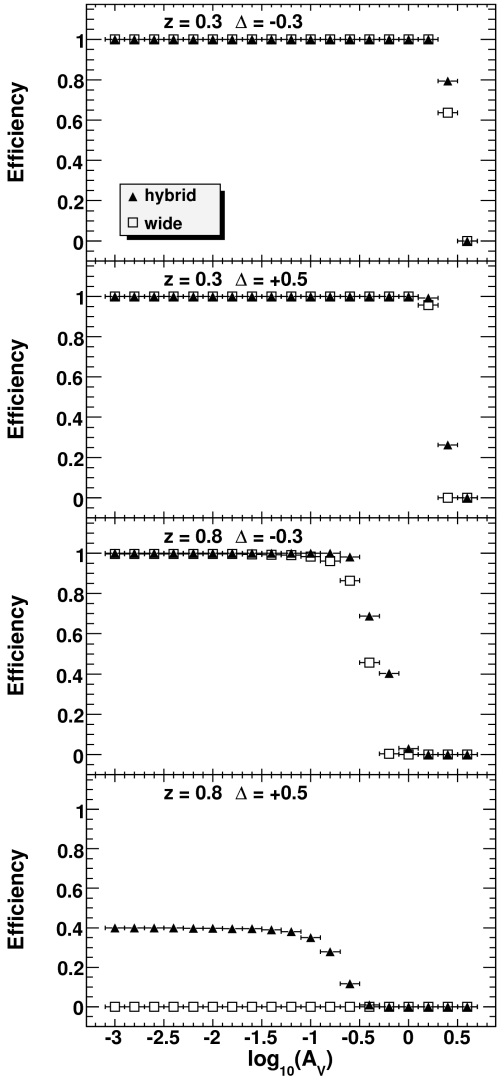


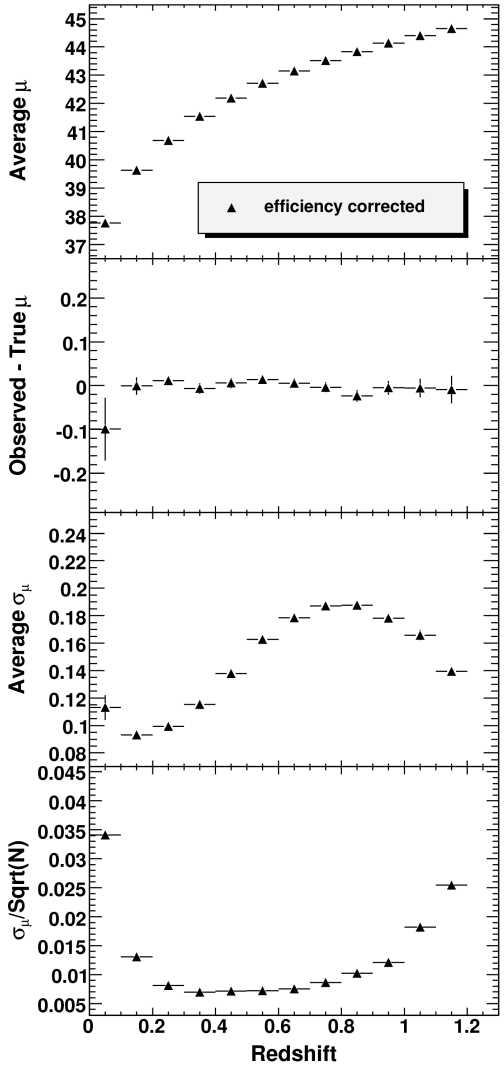
# Number Of Supernovae For Different Strategies



# Selection Bias And The Hubble Diagram Projection

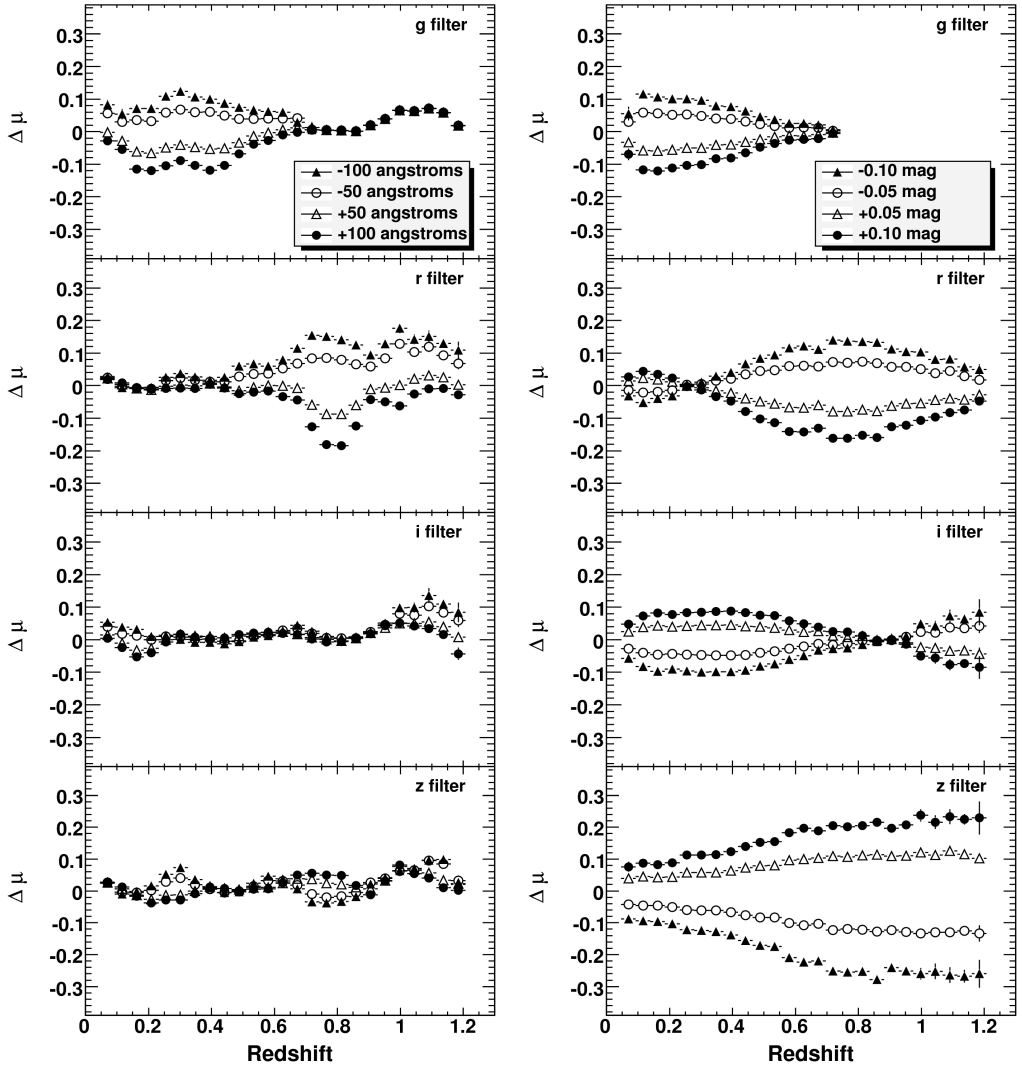


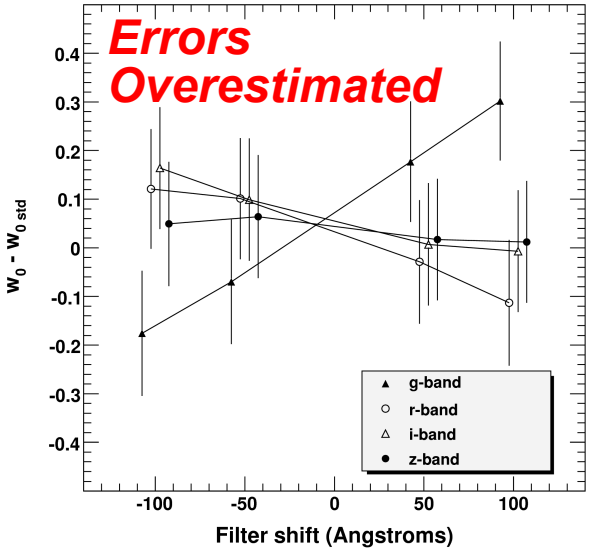



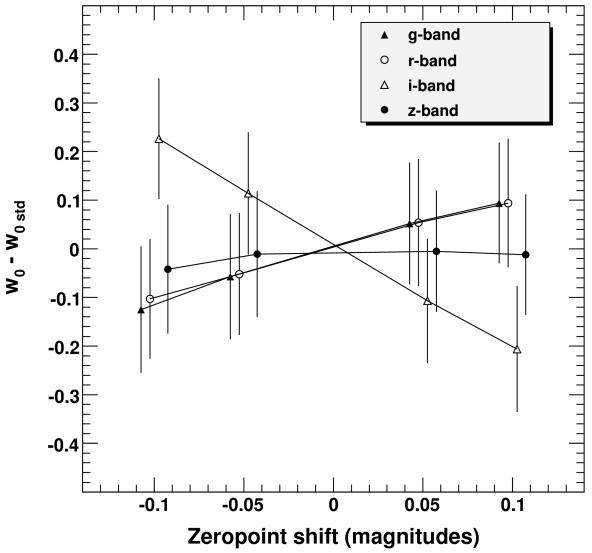



# Effect of Filter Centroid and Zeropoint Shifts

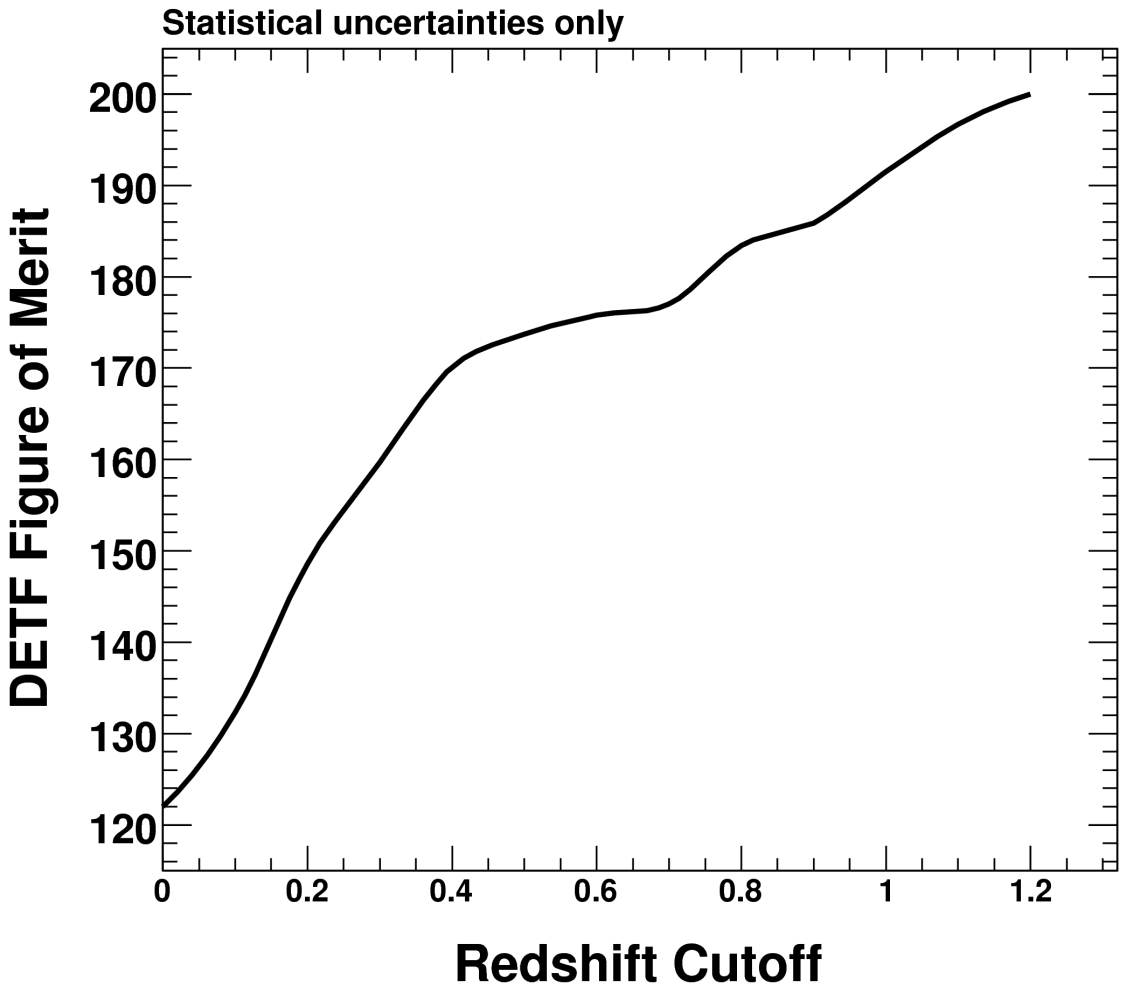
Study by Ribamar Reis



# Spectroscopic Redshift Cutoff and DETF Figure of Merit



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# A COMPARATIVE STUDY OF THE ABSOLUTE MAGNITUDE DISTRIBUTIONS OF SUPERNOVAE

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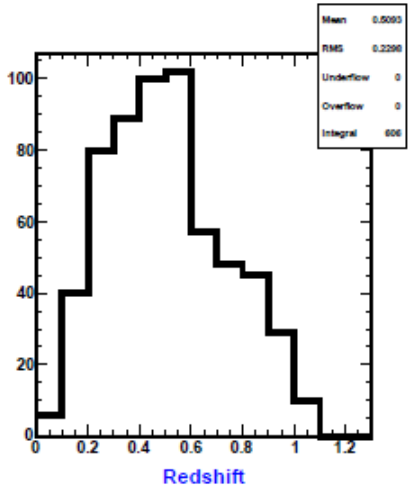
*Received 2001 September 24; accepted 2001 October 24*

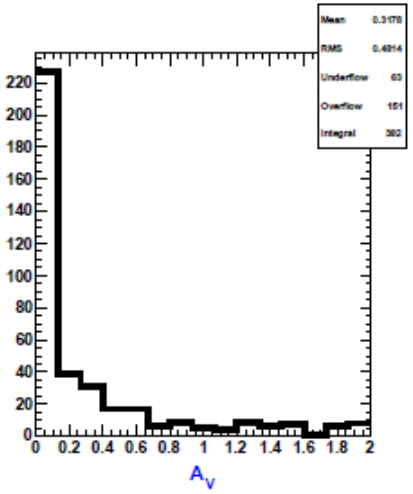
TABLE 1
RESULTS

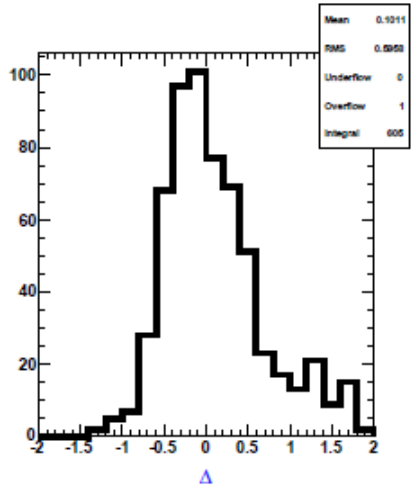
| SN Type | $\overline{M}_{B,\mathrm{obs}}$ | $\sigma_{\mathrm{obs}}$ | $\overline{M}_{B,\mathrm{int}}$ | $\sigma_{\mathrm{int}}$ | Conf. | $N$ |
|---|---|---|---|---|---|---|
| Normal Ia ..... | $-19.16 \pm 0.07$ | 0.76 | $-19.46$ | 0.56 | 0.89 | 111 |
| Total Ibc ..... | $-17.92 \pm 0.30$ | 1.29 | $-18.04$ | 1.39 | 0.96 | 18 |
| Bright Ibc..... | $-19.72 \pm 0.24$ | 0.54 | $-20.26$ | 0.33 | ~1 | 5 |
| Normal Ibc .... | $-17.23 \pm 0.17$ | 0.62 | $-17.61$ | 0.74 | ~1 | 13 |
| Total II-L..... | $-17.80 \pm 0.22$ | 0.88 | $-18.03$ | 0.90 | 0.91 | 16 |
| Bright II-L ..... | $-19.12 \pm 0.12$ | 0.23 | $-19.27$ | 0.51 | ~1 | 4 |
| Normal II-L... | $-17.36 \pm 0.12$ | 0.43 | $-17.56$ | 0.38 | ~1 | 12 |
| II-P ..... | $-16.61 \pm 0.23$ | 1.23 | $-17.00$ | 1.12 | ~1 | 29 |
| IIn..... | $-18.78 \pm 0.31$ | 0.92 | $-19.15$ | 0.92 | ~1 | 9 |

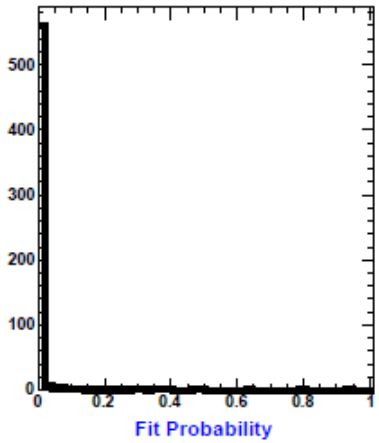
**Fluctuate Nugent templates by numbers from Richardson et al.**

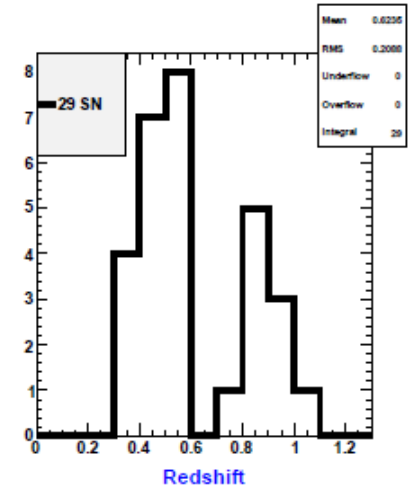
# Example: Nugent Type-Ibc Top 4 plots only SNR cuts

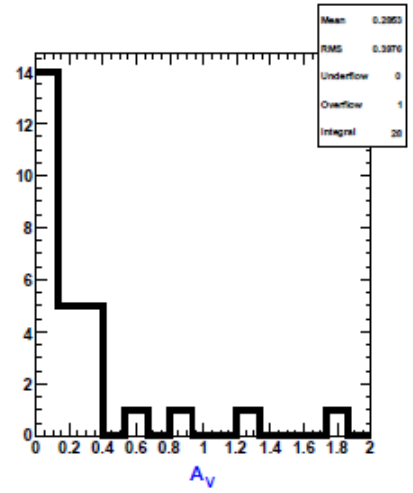


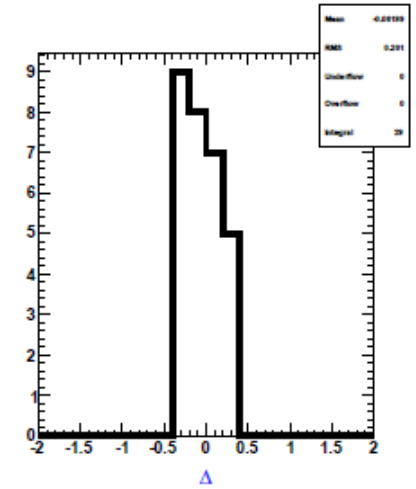



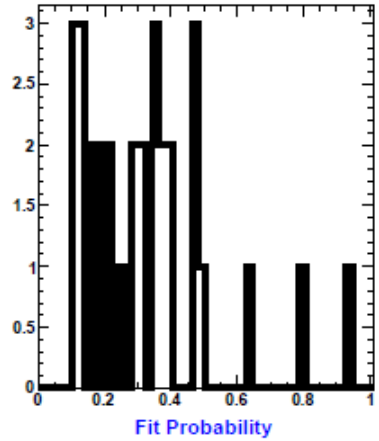




**Bottom 4 plots include cut of fit probability > 0.1**

# SNANA IR Simulations

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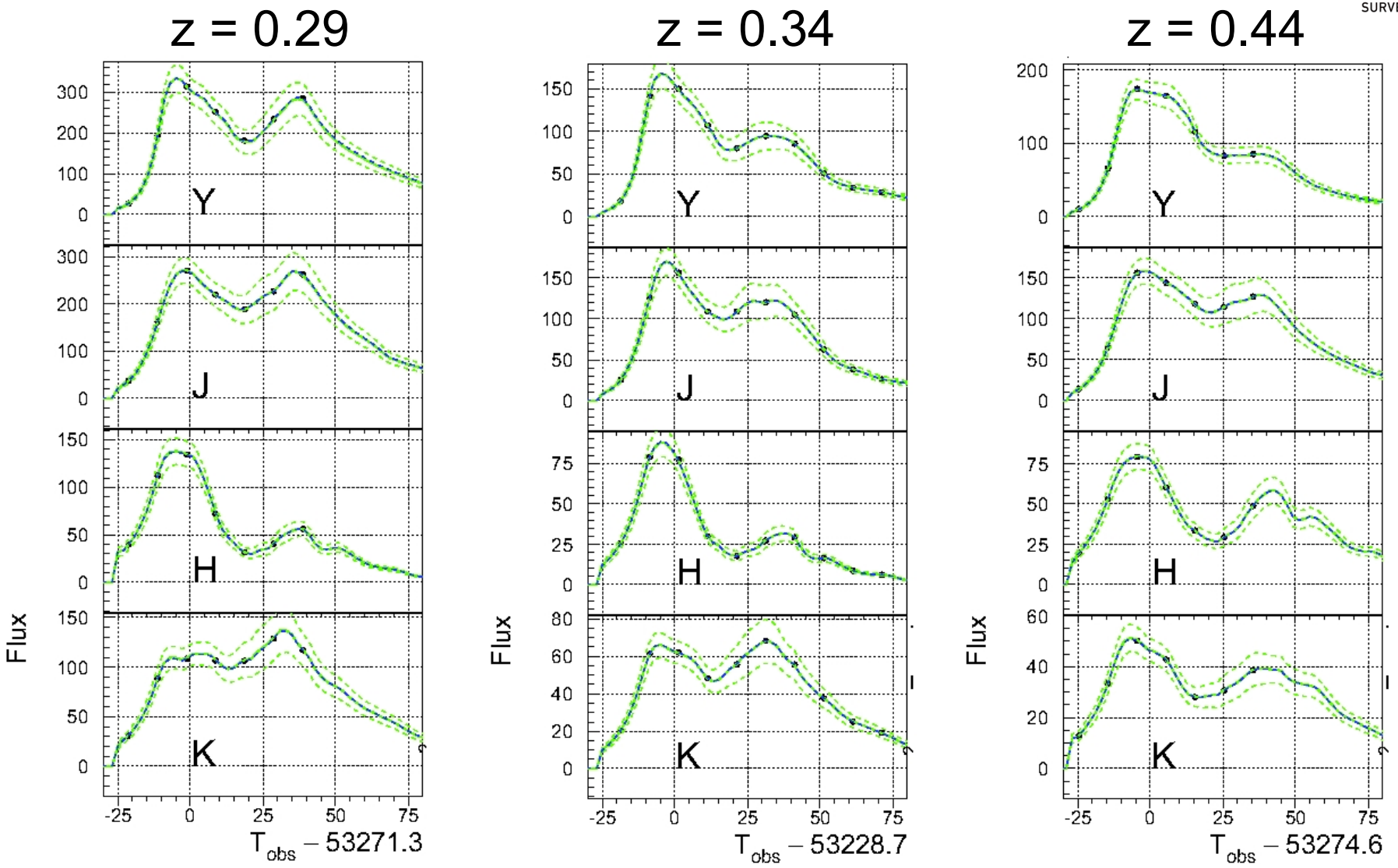
- New IR model for SNANA: mlcs2k2.IR
- UBVRIYJHK filters
- Uses new 9-filter model code
- UBVRI works as mlcs2k2.v006b if YJHK templates do not exist
- NB: $A_V$-prior dominates YJHK fits b/c sim has no lever arm on color

# *"Perfect" VIDEO IR SN Ia Light Curves*



## *Summary & Conclusions*

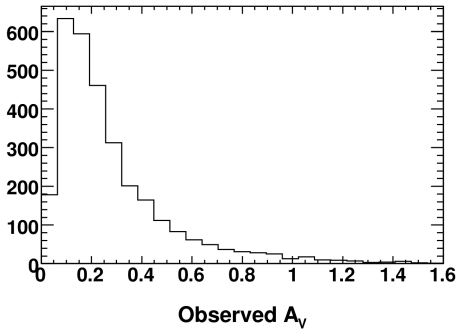
DARK ENERGY SURVEY

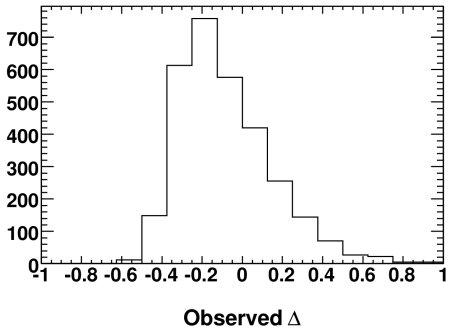
- DES will compile a sample of ~3000 well-measured SNe to z~1
- Hybrid strategy of “deep” and “wide” fields optimal
- DES-SN Strategy simulation paper advancing
  - systematics, non-Ia, and IR studies will complete paper
  - journal submission planned this summer
- Initial SNANA IR model in place
- Follow-on DES/VIDEO IR SN paper next

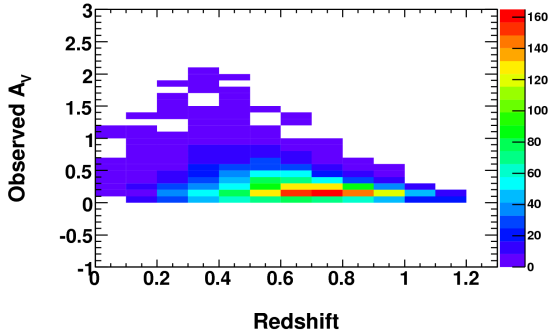
# Backup

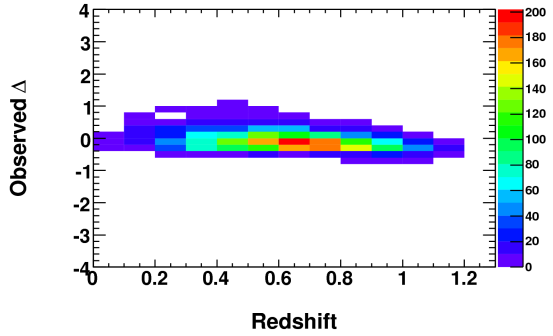
DARK ENERGY SURVEY

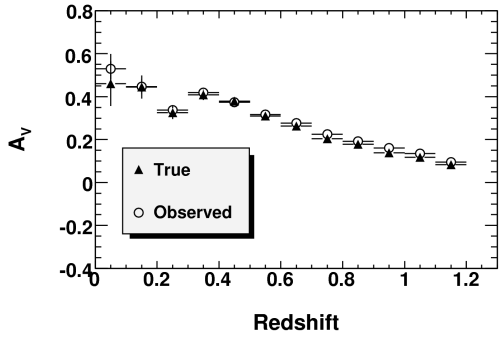
# Extinction ($A_V$) and Light Curve Shape Parameter ($\Delta$)

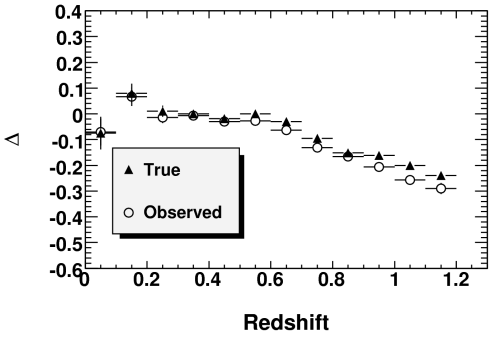
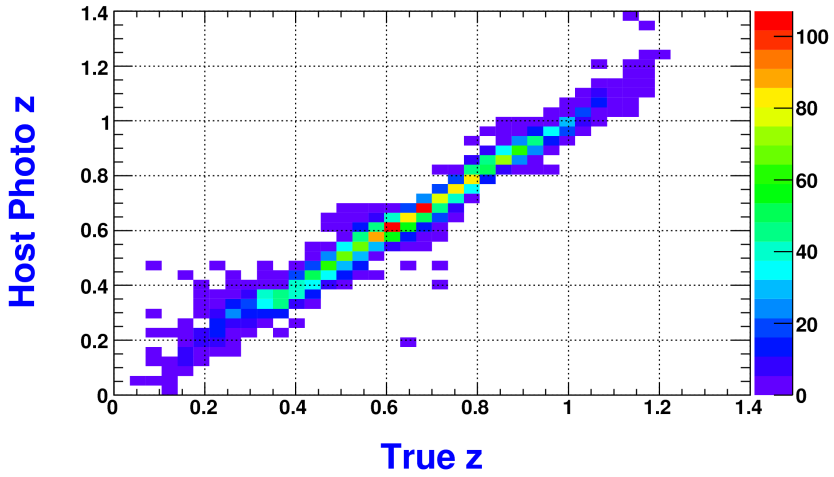
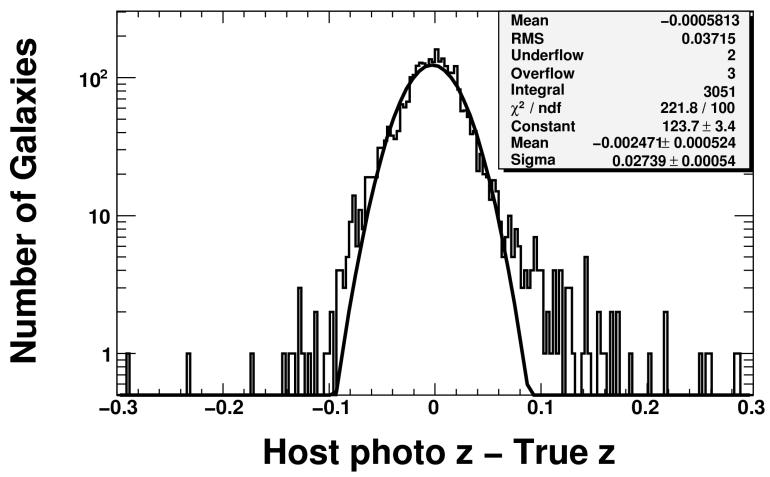
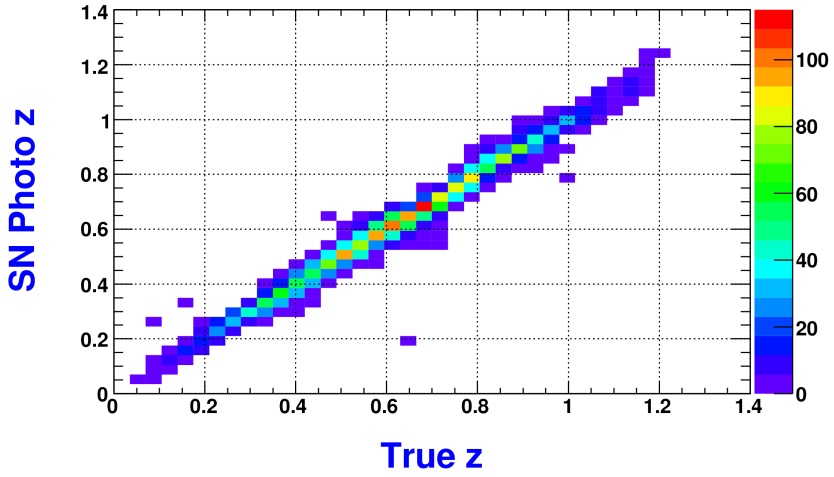
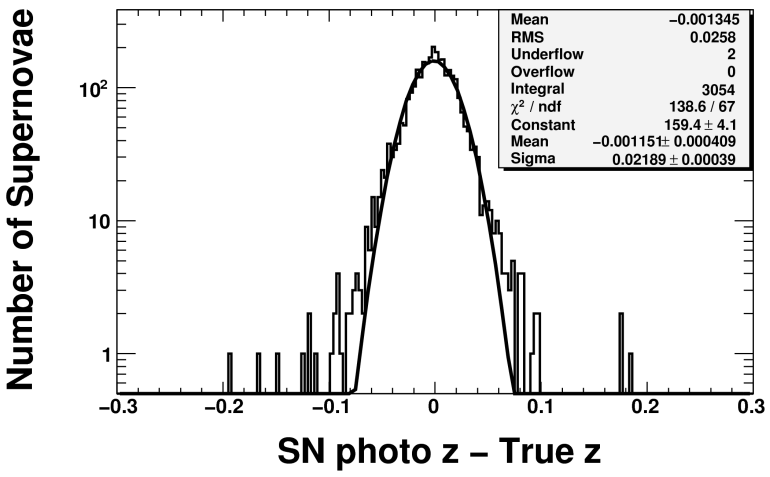





# Photometric Redshifts